SUPPLEMENTATION PLAN
FOR
EARLY RUN ISSAQUAH CREEK KOKANEE

Prepared for
King Conservation District #9

by
Charles W. Hopley
Washington Department of Fish and Wildlife
Fish Program
Science Division
Contract # 33012249

June 2001

TABLE OF CONTENTS

	List of Tables	**ii**
I.	**Introduction**	**1**
II.	**Supplementation and Recovery**	**1**
III.	**Options for Issaquah Creek Early Kokanee Supplementation**	**3**
IV.	**Implementation**	**18**
V.	**Monitoring and Evaluation**	**26**
VI.	**References**	**29**

LIST OF TABLES

Table 1	**Fingerling Release – Option 1**	**6**
Table 2	**Extended Reared Fingerling Release – Option 2**	**9**
Table 3	**Yearling Release – Option 3**	**12**
Table 4	**Captive Brood – Option 4**	**15**
Table 5	**Instantaneous Final Capacities For Each Release-based Option at Initial Program Level**	**23**
Table 6	**Instantaneous Final Capacities For Each Release-based Option at Equilibrium Program Level (1,000 adults)**	**24**
Table 7	**Instantaneous Final Capacities For Captive Brood Option at Initial Program Level (.72 survival rate)**	**25**
Table 8	**Instantaneous Final Capacities For the Captive Brood Option at Equilibrium Program Level (650 adults)**	**26**

I. INTRODUCTION

The precipitous decline of early returning kokanee (Oncorhynchus nerka, freshwater form) to Issaquah Creek (Lake Sammamish, Washington state) has generated concern among resource managers and local governmental entities (Ostergaard 1998; Pfeifer 1999, Pfeifer 1999). Issaquah Creek early-run kokanee have declined from runs between 1,000 and 15,000 prior to 1970 to runs of less than 20 adults between 1992 and 1998 (Connor 2000; Ostergaard 1998; Pfeifer 1999; Pfeifer 1995). Connor et al (2000) projected the rate of decline of approximately 6% between 1980 and 1998 and 9.8% between 1994 and 1998. Pfeifer (1995; 1999) promoted an immediate need for a recovery effort including a hatchery production program.

During CY 2000, the Sammamish Watershed Kokanee Technical Committee identified a pressing need for immediate development of a recovery plan for early run Issaquah Creek kokanee and identified several crucial elements among which was a hatchery-based supplementation plan. King Conservation District #9, with concurrence of the Sammamish Watershed Forum, commissioned the Washington Department of Fish and Wildlife to provide a supplementation plan by July, 2000 (WDFW contract number 33012249). This document is provided in fulfillment of that charge.

The plan identifies a number of alternative hatchery supplementation strategies which might be successfully implemented to increase the numerical abundance of early run Issaquah Creek kokanee. In addition, the plan provides information about the infrastructure necessary to implement each of the alternatives. The contingency format is intended to enable managers and clients to reach an informed decision based on the recovery potential, costs, and risks associated with a range of options. The range of options developed herein is not exhaustive nor is any option mutually exclusive of another. Any number of integrated combinations might be viable. It is recommended that a detailed implementation plan should be developed after the range of options has been narrowed toward a preferred option.

II. SUPPLEMENTATION AND RECOVERY

Supplementation can be described as any among a wide range of artificial propagation activities intended to sustain or increase natural production by using salmonids that are raised in hatcheries for some portion of their life history. Various definitions of supplementation have appeared in the literature (Miller et al. 1990; Smith et al. 1990; Steward and Bjornn 1990). The most comprehensive definition was provided by the Regional Assessment of Supplementation Project (1991):

> *Supplementation is the use of artificial propagation in an attempt to maintain or increase natural production while maintaining the long term fitness of the target*

population, and keeping the ecological and genetic impacts on nontarget populations within specified biological limits.

The use of hatcheries for conservation and recovery of depressed naturally produced populations is being promoted in the northwest (ISG 1996; NRC 1996; NWPPC 1999; Flagg and Nash 1999). Supplementation is a technique or tool that has the potential to complement the conservation and rebuilding role of hatcheries and may play a large part in the recovery of severely depressed salmonid populations such as early run Lake Sammamish kokanee.

Hatcheries may be useful in the recovery of depressed stocks because of the potential to circumvent high rates of mortality experienced at various life stages in the wild. As a result, artificial propagation measures have proven effective in many cases at alleviating near-term extinction risks (NMFS 2000). To be successful in the long term, a conservation hatchery should breed and propagate a stock of fish with genetic resources equivalent to the natural stock, and with full ability to return to reproduce naturally in its native habitat (Flagg and Nash 1999). However, artificial propagation entails risks as well as opportunities and its ability to supplement and restore natural production is largely unknown (Hart et al. 1992; Miller et al. 1990).

To afford the greatest opportunity for success, managers must be aware of the potential sources of hazard and plan to the extent possible to reduce or minimize the potential for negative impacts. Two general categories of hazard are frequently identified in relation to supplementation hatchery operations; genetic hazard and ecological interactions hazard. Busack and Currens (1995) described four major types of genetic hazard for consideration in hatchery planning.

Extinction – the complete loss of all genetic information.

Loss of Within-Population Variability – the reduction in quantity, variety, and combinations of alleles in a population.

Loss of Among-Population Variability – the reduction in differences in quantity, variety, and combinations of alleles among populations.

Domestication – changes in quantity, variety, or combination of alleles within a captive population or between a captive population and its source population in the wild as a result of selection in an artificial environment.

Numerous types of ecological interactions hazards could be tabulated but hazards of immediate concern for this project can be generalized into two major types; competition and predation.

Often these hazards are presented in terms of risk posed by hatchery programs to the surrounding biota. Given the critical state of early run Issaquah Creek kokanee, genetic and ecological hazards should be considered in the context of the risk they pose to success of the

kokanee recovery plan. Both sources of risk, genetic and ecological, have implications for the success of the project, but they need not be viewed as barriers to action. The salient point is to recognize and identify the potential forms and sources for hazards and incorporate operational plans designed to minimize the effects of the identified hazards. For example, the use of mating schemes that maximize effective population size and retain the highest level of genetic diversity must be called for in the recovery plan and incorporated in detailed operating plans to reduce the risk from genetic hazards. Risk averse operating plans should be bolstered by monitoring plans that provide feedback relative to the success of risk management efforts and expectations. Each of the fish production options developed in the next section includes short comments on sources of risk pertinent to consideration of that option.

Supplementation programs are sometimes initiated as a safety net designed only to prevent extinction. This is certainly descriptive of the initial situation with early run Issaquah Creek kokanee. Usually supplementation programs are not permanent and they do not serve as substitutes for addressing the factors of decline (NMFS 2000). Supplementation should be integrated with a recovery plan that addresses factors causing the decline (Hard et al. 1992). In the case of early run Issaquah Creek kokanee, a number of possible sources of downward pressure on the productivity of kokanee in Lake Sammamish have been listed and described (eg. Pfeifer 1995; Connor 2000). The proposed supplementation plan can only be successful if incorporated into an overall recovery plan designed to address sources of mortality for early Issaquah Creek kokanee. The recovery plan must result in action and must be conducted concurrent with supplementation activities or increasing natural productivity of the supplemented population will be unlikely.

III. OPTIONS FOR ISSAQUAH CREEK EARLY KOKANEE SUPPLEMENTATION

Five supplementation options are presented in this section based on the following hatchery-based strategies: 1) fingerling releases; 2) extended reared fingerling releases; 3) yearling releases; 4) captive brood, and; 5) no action. The options are considered within the context of proposed objectives. Each of the action alternatives is operationally practicable using common fish culture implements and rearing practices. A general description is first provided for each option. A range of quantified fish production outcomes is then discussed and expressed in tabular form for each option based on assumptions specific to that option. These production outcomes are calculated based on ranges of egg, fry, fingerling, and post-release survival rates drawn from published reports (Flagg et al. 2000; Flagg and Mahnken 1995; Beauchamp et al. 1995; Murdoch and Petersen 2000; Marlowe et al 2001), WDFW hatchery operating documents (WDFW 1996; Fuss and Ashbrook 1995) and personal communications with kokanee and sockeye culturists (Rankin, John and Bruce Thompson, Sullivan Springs Hatchery, IDFG; Kline, Paul, Eagle Hatchery, IDFG; Peone, Tim, Spokane Tribal Hatchery, Spokane Tribe of Indians). However, the use of ranges reflects the paucity of empirical information from which to directly predict specific survival responses at each life stage for Lake Sammamish kokanee. All outcomes are, however, believed to be plausible. The presentation of plausible outcomes is followed by a consideration of risk factors and the efficacy of each option relative to that factor. The

consideration of risk and efficacy combined with projected plausible outcomes is provided to assist in selection of a preferred option.

Each action option shares the following common assumptions about initial brood stock collection from which all subsequent production will be derived.

Initial Assumptions:

Matings:	between 5 and 25 females (10 to 50 adults)
Sex Ratio:	1:1
Fecundity:	400 eggs per female
Age-at-maturity:	4-yr-old

Additional assumptions for specific options are presented below as appropriate.

SUPPLEMENTATION OBJECTIVES

Objectives for Release-based Options

- Increase brood stock return, egg collection, and hatchery release numbers to achieve an equilibrium return of 1,050 adult spawners each year consisting of 750 adults for use in the hatchery and 300 adults for natural escapement. Minimum effective population size (N_e) for long-term conservation of genetic resources is about 1,000 adults per generation divided by the generation time. This would suggest an adult escapement N_e need of 250 adults for the hatchery each year. An additional escapement of 100 adults for natural spawning also recommended. However, the effective population size is thought to be about 1/3 of the census population. Therefore, to achieve an effective population size of 250 adults for hatchery brood stock and 100 adults for wild escapement for each 4-yr-old age class, a census population of 1,050 is required (Craig Busack, personal communication, WDFW, Olympia WA.). Secondarily, this escapement level is consistent with the lower range of estimates for historical escapement levels provided by Connor (2000) and Pfeifer (1995).
- Discontinue hatchery supplementation following decision criteria to be developed in the kokanee recovery plan.

Objectives for Captive Brood Option

- Increase brood stock numbers, egg collection, and fry production numbers to achieve an equilibrium captive brood program that will provide hatchery releases great enough to produce 1,050 adults for natural escapement annually, following the same derivation as presented above. This will require about 650 mature adults in the captive brood program each year.
- Discontinue captive brood program following decision criteria to be developed in the kokanee recovery plan.

SUPPLEMENTATION OPTIONS

OPTION 1 - Fingerling Release

General Description

This option will primarily circumvent limitations that occur at the time of spawning, during egg incubation, hatching, emergence and early emigration. This option would be attractive if it is assumed that survival bottlenecks occur at some point from spawning to downstream migration. Conversely, it would be assumed that post-emigration factors are not the factors limiting productivity.

For the initial cycle, eggs from 5 to 25 females (2,000 to 10,000) will be fertilized following a prescribed mating protocol and incubated in isolation incubation buckets and vertical incubator trays, separated by family lots, until hatching. Resulting fry will be transferred to rearing vessels in individual family lots and reared according to prescribed criteria. As fry achieve adequate size they will be marked according to family and redistributed to rearing vessels of appropriate capacity to accommodate continued growth. Fingerlings will be reared to 50 fish/lb (9g) and released into Issaquah Creek in June after approximately 2 months of rearing. Returning adult brood stock would be recovered within Issaquah Creek to generate the subsequent rearing cycle.

Outcomes

Outcomes were calculated for six production scenarios over a duration of five generations (Table 1). Specifically, egg production, fry production, fingerling releases, and adult return numbers were calculated from two initial brood stock levels (five and 25 pairs) and three post-release survival rates (.01, .015, .02).

For scenarios based on five initial matings, hatchery releases large enough to produce adult escapement exceeding 1,050 can be expected within five generations if post-release survival is about .02. Projections improve for scenarios based on 25 initial matings. For a survival rate of .01, adequate hatchery releases to meet the objective are not attained within the first five generations. Releases large enough to produce adult escapement exceeding 1,050 are possible in the third generation at a post-release survival rate of .02 (1,296) and in the fourth generation at a post-release survival of .015 (1,220).

Table 1. Fingerling Release – Option 1

Assumptions:

Weight: 50 fish/lb (9grams) Length: 3.7 inches (94mm) Matings: 5 to 25 pair (10 to 50 adults) Sex Ratio: 1:1 Fecundity: 400	Survival Rates: Egg-to-fry = 0.87 Fry-to-release = 0.85 Release-to-adult = 0.01; 0.015; 0.02

Year 2001		Scenario 1: 10 adults or 5 matings			Scenario 2: 50 adults or 25 matings		
F1 generation		Eggs: 2,000 Fry: 1,740 Fingerlings Released: 1,479			Eggs: 10,000 Fry: 8,700 Fingerlings Released: 7,395		
	Survival rates	0.01	0.015	0.02	0.01	0.015	0.02
	Adults	15	22	30	74	111	148
F2 generation							
	Eggs	3,200	4,400	6,000	14,800	22,400	29,600
	Fry	2,784	3,828	5,220	12,876	19,488	25,752
	Fingerling Release	2,366	3,254	4,437	10,945	16,565	21,889
	Adults	24	49	89	109	248	438
F3 generation							
	Eggs	4,800	10,000	18,000	22,000	49,600	87,600
	Fry	4,176	8,700	15,660	19,140	43,152	76,212
	Fingerling release	3,550	7,395	13,311	16,269	36,679	64,780
	Adults	36	111	266	163	550	1,296
F4 generation							
	Eggs	7,200	22,400	53,200	32,800	110,000	259,200
	Fry	6,264	19,488	46,284	28,536	95,700	225,504
	Fingerling release	5,324	16,565	39,341	24,256	81,345	191,678
	Adult	53	248	787	243	1,220	3,834
F5 generation							
	Eggs	10,800	49,600	157,600	48,800	244,000	766,800
	Fry	9,396	43,152	137,112	42,456	212,280	667,116
	Fingerling release	7,987	36,679	116,545	36,088	180,438	567,049

Risk Elements

Fish Culture

Facilities – Among the hatchery-based options, this is the least capital intensive and will have the lowest operating costs. Rearing capacity requirements will be minimal and the rearing period will be relatively short; only several months out of each year. Feed costs will be minimal because few total pounds of production will be gained.

Survival rates – There is a great deal of uncertainty about the survival rates that might actually be achieved. Post-release survival rates are among the most critical assumptions used to derive the outcomes presented above. For this option, productivity was calculated using post-release survival rates ranging from .01 to .02. There is evidence that these rates can be achieved in certain cases. It is not known, however, what the appropriate rate is for Lake Sammamish kokanee. There is no certainty that the actual rate achieved will fall within this range.

Fish health – Disease can be a limiting factor for fish culture operations. There are well established practices for addressing common fish health issues. The diseases of most concern for this proposal are IHN and Bacterial Kidney Disease (BKD). The short-term rearing cycle for this option reduces but does not eliminate the potential for these diseases which can be catastrophic. Routine fish health inspections and aggressive disease prevention practices will be incorporated to lessen potential for major negative impacts of disease.

Genetic

Extinction – This option reduces the risk of extinction relative to the no-action option if a successful fish culture operation is assumed and survival rates at various life stages are achieved.

Within-population variation – This option prevents further deterioration of within-population variation if prescribed spawning protocols are followed and survival rates at various life stages are achieved for each mating.

Among-population variation – This option is expected to maintain population structure and will be managed to avoid introgression with other genetic populations.

Domestication selection – The risk of domestication selection is lowest among the fish culture-based options presented because this option proposes the shortest period of time during which kokanee are exposed to culture conditions. The option poses more risk to domestication selection than the no-action option.

Ecological

Predation – As described above, there is ample evidence to suggest that predation may be among the most significant risks for kokanee in Lake Sammamish. Option 1 will provide protection from predation at the egg and fry life history stages. Among the four fish culture-based options evaluated, Option 1 would be expected to provide the least insulation from predation after fish are released to the natural environment. Fish are released at a relatively small size (3.7 inches) and would be vulnerable to larger predators such as cutthroat, smallmouth bass, and northern pike minnow.

Competition – There are a number of potential forms of competition that could come into play for this and other options including competition for prey and space. This option will negate the effects of competition during the fish culture phase. However, too little is known about Lake Sammamish kokanee life history and its relationship to lake productivity, habitat, and limnology to provide an informed discussion about the potential for competition after release. Literature suggests that competition would not be a significant limiting factor at current low population levels.

OPTION 2 - Extended-reared Fingerling Release

General Description

This option will primarily circumvent limitations that occur between the time of spawning and initial rearing in the lacustrine environment. This option would be attractive if it is assumed that survival bottlenecks occur at some point from spawning through early rearing in the lake. Conversely, it would be assumed that the lake rearing environment is not limiting productivity between the summer of first entry to the lake and adult maturation.

For the initial cycle, eggs from 5 to 25 females (2,000 to 10,000) will be fertilized following a prescribed mating protocol and incubated in isolation incubation buckets and vertical incubator trays, separated by family lots, until hatching. Resulting fry will be transferred to rearing vessels in individual family lots and reared according to prescribed criteria. As fry achieve adequate size they will be marked according to family and redistributed to rearing vessels of appropriate capacity to accommodate continued growth. Fingerlings will be reared to 30 fish/lb (15g) and released into Issaquah Creek in October after approximately 6 months of rearing. Returning adult brood stock would be recovered within Issaquah Creek to generate the subsequent rearing cycle.

Outcomes

Outcomes were calculated for six production scenarios over a duration of five generations (Table 2). Specifically, egg production, fry production, fingerling releases, and adult return numbers were calculated from two initial brood stock levels (five and 25 pairs) and three post-release survival rates (.015, .02, .025).

Initial brood availability continues to be severely limiting for this option. For scenarios based on five initial matings, fingerling releases large enough to produce adult escapement exceeding 1,050 are possible in the fourth generation if a post-release survival rate of .025 can be attained and in the fifth generation at .02 survival rate (1,524 and 1,692 adults, respectively). For scenarios based on 25 initial matings, releases large enough to produce adult escapement exceeding 1,050 are possible in the third generation if survival rates meet or exceed .02 and are approached in the fourth generation at a survival rate of .015. (952 adults).

Table 2. Extended Reared Fingerling Release – Option 2							
Assumptions:							
Weight: 30 fish/lb (15 grams) Length: 4.4 inches (112 mm) Matings: 5 to 25 pair (10 to 50 adults) Sex Ratio: 1:1 Fecundity: 400				Survival Rates: Egg-to-fry = 0.87 Fry-to-release = 0.80 Release-to-adult = 0.015; 0.02; 0.025			
Year 2001		Scenario 1: 10 adults or 5 matings			Scenario 2: 50 adults or 25 matings		
F1 generation		Eggs: 2,000 Fry: 1,740 Fingerlings Released: 1,392			Eggs: 10,000 Fry: 8,700 Fingerlings Released: 6,960		
	Survival Rates	0.015	0.02	0.025	0.015	0.02	0.025
	Adults	21	28	35	104	139	174
F2 generation							
	Eggs	4,400	5,600	7,200	20,800	28,000	34,800
	Fry	3,828	4,872	6,264	18,096	24,360	30,276
	Fingerling Release	3,062	3,898	5,011	14,477	19,488	24,221
	Adults	46	78	125	217	390	606
F3 generation							
	Eggs	9,200	15,600	25,200	43,600	78,000	121,200
	Fry	8,004	13,572	21,924	37,932	67,860	105,444
	Fingerlings released	6,403	10,858	17,539	30,346	54,288	84,355
	Adults	96	217	438	455	1,086	2,109
F4 generation							
	Eggs	19,200	43,600	87,600	91,200	217,200	422,000
	Fry	16,704	37,932	76,212	79,344	188,964	367,140
	Fingerlings released	13,363	30,346	69,970	63,475	151,171	293,712
	Adults	200	607	1,524	952	3,023	7,343
F5 generation							
	Eggs	40,000	121,600	304,800	190,400	604,800	1,468,800
	Fry	34,800	105,792	265,176	165,648	526,176	1,277,856
	Fingerlings released	27,840	84,634	212,141	132,518	420,941	1,022,285

Risk Elements

Fish Culture

Facilities – This option will require somewhat higher capital and operating costs than Option 1 but significantly less than Options 3 or 4. Although slightly more rearing space and water is needed, only a single crop of fish will be at the hatchery site in any given year.

Rearing capacity requirements will be limited and the rearing period will be relatively short; only several months out of each year. Feed costs, while still minimal, will be about 60% greater than Option 1 because fish will be raised for a longer period of time and released at a larger size.

Survival rates – There is a great deal of uncertainty about the survival rates that might actually be achieved. Post-release survival rates are among the most critical assumptions used to derive the outcomes presented above. For this option, productivity was calculated using post-release survival rates ranging from .01 to .02. There is evidence that these rates can be achieved in certain cases. It is not known, however, what the appropriate rate is for Lake Sammamish kokanee. There is no certainty that the actual rate achieved will fall within this range.

Fish health – Disease can be a limiting factor for fish culture operations. There are well established practices for addressing common fish health issues. The diseases of most concern for this proposal are IHN and Bacterial Kidney Disease (BKD). The short-term rearing cycle for this option reduces but does not eliminate the potential for these diseases which can be catastrophic. Routine fish health inspections and aggressive disease prevention practices will be incorporated to lessen potential for major negative impacts of disease.

Genetic

Extinction – This option reduces the risk of extinction relative to the no-action option and Option 1, primarily due to expectations for marginally greater post-release survival rates. A successful fish culture operation is assumed. If the fish culture approach is not successful then extinction risk could equal or exceed that of the no-action option.

Within-population variation – This option prevents further deterioration of within-population variation if prescribed spawning protocols are followed and survival rates at various life stages are achieved for each mating.

Among-population variation – This option is expected to maintain population structure and will be managed to avoid introgression with other genetic populations.

Domestication selection – The risk of domestication selection is believed to increase with greater length of exposure to rearing under artificial production. This option poses more risk of domestication selection than the no-action option or Option 1.

Ecological

Predation – As described above, there is ample evidence to suggest that predation may be among the most significant risks for kokanee in Lake Sammamish. Option 2 will provide protection from predation at the egg, fry and fingerling life history stages during the time

of residency in the hatchery. This option will provide greater post-release protection from predation than will Option 1 because fish are released at a relatively larger size (4.4 inches) but would still be vulnerable to larger predators such as cutthroat, smallmouth bass, and northern pike minnow.

Competition – There are a number of potential forms of competition that could come into play for this and other options including competition for prey and space. This option will negate the effects of competition during the fish culture phase but will expose fingerlings to potential competitive factors following release in the spring. However, too little is known about early-run kokanee life history in Lake Sammamish and its relationship to lake productivity, habitat, and limnology to draw conclusions about the potential for competition after release. Literature suggests that competition would not be a significant limiting factor at current low population levels.

OPTION 3 - Yearling Release

General Description

This option will primarily circumvent limitations that occur from spawning through the first year of life. This option would be attractive if it is assumed that survival bottlenecks occur during early life stages including the first year of lake residency. This alternative might also be attractive if one assumed that a large size at release would provide a survival advantage. Conversely, it would be assumed that the lake rearing environment was not a factor limiting productivity for kokanee of yearling size or greater.

For the initial cycle, eggs from 5 to 25 females (2,000 to 10,000) will be fertilized following a prescribed mating protocol and incubated in isolation incubation buckets and vertical incubator trays, separated by family lots, until hatching. Resulting fry will be transferred to rearing vessels in individual family lots and reared according to prescribed criteria. As fry achieve adequate size they will be marked according to family and redistributed to rearing vessels of appropriate capacity to accommodate continued growth. Yearlings will be reared to 15 fish/lb (30g) and released into Issaquah Creek in May-June after approximately 14 months of rearing. Returning adult brood stock would be recovered within Issaquah Creek to generate the subsequent rearing cycle.

Outcomes

Outcomes were calculated for eight production scenarios over a duration of five generations (Table 3). Specifically, egg production, fry production, yearling release numbers, and adult return numbers were calculated from two initial brood stock levels (five and 25 pairs) and four post-release survival rates (.02, .03, .05, .10).

With an assumption of higher potential survival rates for kokanee released as yearlings at 15 fish per pound (30g), initial brood availability might be somewhat less limiting. For scenarios

based on five initial matings, fingerling releases large enough to produce adult escapement exceeding 1,050 could be achieved in the second generation at a survival rate of .10 (1,723 adults). It would be in the third generation that releases large enough to produce 1,050 adults could be achieved for post-release survival of .05 (2,819 adults) and in the fourth generation for survival of .03 (2,427 adults). In the fifth generation, 1,216 adults might be produced if the survival rate after release is .02.

For scenarios based on 25 initial matings, releases large enough to produce adult escapement exceeding 1,050 might be observed by the second generation if survival rates fall some place between .03 and .05. This adult escapement could be exceeded under all post-release survival assumptions except .02 by the third generation. By the fourth generation, all post-release survival scenarios would produce adults in excess of the objective.

Table 3. Yearling Release – Options 3

Assumptions:

Weight: 15 fish/lb (30 grams)
Length: 5.5 inches (140 mm)
Matings: 5 to 25 pair (10 to 50 adults)
Sex Ratio: 1:1
Fecundity: 400

Survival Rates:
Egg-to-fry = 0.87
Fry-to-Release = 0.75
Release-to-adult = 0.02; 0.03; 0.05; 0.10

Year 2001		Scenario 1: 10 adults or 5 matings				Scenario 2: 50 adults or 25 matings			
F1 generation		Eggs: 2,000 Fry: 1,740 Yearlings Released: 1,305				Eggs: 10,000 Fry: 8,700 Yearlings Released: 6,525			
Survival Rates		0.02	0.03	0.05	0.10	0.02	0.03	0.05	0.10
	Adults	26	39	65	131	131	196	326	653
F2 generation									
	Eggs	5,200	8,000	13,200	26,400	26,400	39,200	65,200	130,800
	Fry	4,524	6,960	11,484	22,968	22,968	34,104	56,724	113,796
	Yearlings Released	3,393	5,220	8,613	17,226	17,226	25,578	42,543	85,347
	Adults	68	157	431	1,723	345	767	2,127	8,535
F3 generation									
	Eggs	13,600	31,600	86,400	344,800	69,200	153,600	425,600	1,707,200
	Fry	11,832	27,492	75,168	299,976	60,204	133,632	370,272	1,485,264
	Yearlings Released	8,874	20,619	56,376	224,982	45,153	100,224	277,704	1,113,948
	Adults	177	619	2,819	2,819	903	3,007	13,885	111,395
F4 generation									
	Eggs	35,600	124,000	564,000	4,499,600	180,800	601,600	2,777,200	22,279,200
	Fry	30,972	107,880	490,680	3,914,652	157,296	523,392	2,416,164	19,382,904
	Yearlings Released	23,229	80,910	368,010	2,935,989	117,972	392,544	1,812,123	14,537,178
	Adults	465	2,427	18,401	293,599	2,359	11,776	90,606	1,453,718
F5 generation									
	Eggs	93,200	485,600	3,680,400	58,720,000	472,000	2,355,200	18,121,200	290×10^6
	Fry	81,084	422,472	3,201,948	51,086,400	410,640	2,049,024	15,765,444	252×10^6

	Yearlings Released	60,813	316,854	2,401,461	38,314,800	307,980	1,536,768	11,824,083	189×10^6

Risk Elements

Fish Culture

Facilities – This option is relatively cost intensive, primarily because two brood years of production must be on site concurrently. Rearing capacity must be provided for yearling fish nearing the end of the rearing cycle and for the ensuing crop of juveniles in their initial rearing stages. Feed costs will be significantly greater that Options 1 or 2 but far less than that experienced in traditional production hatcheries due to the limited numbers of fish proposed for rearing.

Survival rates – There is a great deal of uncertainty about the survival rates that might actually be achieved. Post-release survival rates are among the most critical assumptions used to derive the outcomes presented above. For this option, productivity was calculated using post-release survival rates ranging from .02 to .10. There is evidence that survival rates in the lower end of this range can be achieved in certain cases. There is no specific evidence for survival rates near the top of the range although these rates are often met or exceeded with yearling production of other species. It is not known what the appropriate rate is for Lake Sammamish kokanee and there is no certainty that the actual rate achieved will fall within this range.

Fish health – Disease can be a limiting factor for fish culture operations. There are well established practices for addressing common fish health issues. The diseases of most concern for this proposal are IHN and Bacterial Kidney Disease (BKD). Hatchery fish being raised to yearling size are most susceptible to BKD which typically strikes in the fall at the end of the first year of culture. Losses can be catastrophic. Routine fish health inspections and aggressive disease prevention practices will be incorporated to lessen potential for major negative impacts of disease.

Genetic

Extinction – This option reduces the risk of extinction relative to the previous options, primarily due to expected higher post-release survival of yearling fish. A successful fish culture operation is assumed. If the fish culture approach is not successful then extinction risk could equal or exceed that of the no-action option.

Within-population variation – This option prevents further deterioration of within-population variation if prescribed spawning protocols are followed and survival rates at various life stages are achieved for each mating.

Among-population variation – This option is expected to maintain population structure

and will be managed to avoid introgression with other genetic populations.

Domestication selection – The risk of domestication selection increases for this options because period of time during which kokanee are exposed to culture conditions is extended relative to the previous options.

Ecological

Predation – As described above, there is ample evidence to suggest that predation may be among the most significant risks for kokanee in Lake Sammamish. Option 3 will provide the greatest protection against predation among the fish release options. All life stages are protected during the first year of life because they are residing in the hatchery environment. The relatively large size at release as yearlings (5.5 inches) would provide an enhanced level of protection from large cutthroat, smallmouth bass, and northern pike minnow.

Competition – There are a number of potential forms of competition that could come into play for this and other options including competition for prey and space. This option will negate the effects of competition during the fish culture phase. However, too little is known about kokanee life history in Lake Sammamish and its relationship to lake productivity, habitat, and limnology to support strong conclusions about the potential for competition after release. Literature suggests that competition would not be a significant limiting factor at current low population levels.

OPTION 4 - Captive Brood

General Description

This option will circumvent all life stage risks encountered in the natural environment. This option assumes that all life stages are limiting in the natural environment or that life stage limiting factors are not known. This option also assumes that life stage cumulative mortality rates will be reduced in the hatchery compared to the wild and that net reproductive efficiency will be greater in the hatchery than in the wild.

For the initial cycle, eggs from 5 to 25 females (2,000 to 10,000) will be fertilized following a prescribed mating protocol and incubated in isolation incubation buckets and vertical incubator trays, separated by family lots, until hatching. Resulting fry will be transferred to rearing vessels in individual family lots and reared according to prescribed criteria. As fry achieve adequate size they will be marked according to family and redistributed to rearing vessels of appropriate capacity to accommodate continued growth. Fingerlings will be retained and reared to adult maturation. Adults will be spawned according to prescribed mating protocols to assure maximum effective population size and to avoid sibling matings.

Outcomes

Outcomes were calculated for six production scenarios over a duration of two generations (Table 4). Specifically, egg production and fry production numbers were calculated for two initial brood stock levels (five and 25 pairs) and three survival rates to adult maturation (.30, .50, .72).

For the range of survival rates tested, the equilibrium level of 650 adults per year could be exceeded with the first generaton for all scenarios except the lowest survival rate, .30. Adequate fingerling releases to produce 1,000 adult natural spawners from captive brood parents could be expected by the third generation under all assumptions tested and by the second generation with all but the lowest estimate of survival for captive brood parents. If up to 25 matings were produced for the first cycle, all equilibrium production levels would be achieved by the second generation for all survival assumptions tested.

Table 4. Captive Brood – Option 4

Assumptions:

Weight: 1 fish/lb (454 grams) Length: 13 inches (330 mm) Matings: 5 to 25 pair (10 to 50 adults) Sex Ratio: 1:1 Fecundity: 400	Survival Rates: Wild egg-to-fry = 0.87 Captive egg viability = 0.50 Captive eyed egg-to-fingerling = 0.85 Captive fry-to-adult = 0.30; 0.50; 0.72

Year 2001		Scenario 1: 10 adults or 5 matings			Scenario 2: 50 adults or 25 matings		
F1 generation		Eggs: 2,000 Fry: 1,740			Eggs: 10,000 Fry: 8,700		
Fry-to-adult survival rate		0.30	0.50	0.72	0.30	0.50	0.72
	Adults	522	870	1,253	2,610	4,350	6,264
F2 generation							
	Eggs	104,400	174,000	250,800	522,000	870,000	1,252,800
	Eyed eggs	52,200	87,000	125,400	261,000	435,000	626,400
	Fry	44,370	73,950	106,590	221,850	369,750	532,440

Risk Elements

Fish Culture

Facilities – Among the hatchery-based options, this is the most capital intensive and will have the highest operating costs. Rearing capacity adequate to retain four brood years concurrently will be required. Annual feed costs will be higher than other options but still low compared to feed requirements of traditional production hatcheries.

Survival rates – There is a great deal of uncertainty about the survival rates that might actually be achieved. Survival rates are among the most critical assumptions used to derive the outcomes presented above. For this option, egg viability in the second and subsequent generations was set at .5 and eyed egg-to-adult production was calculated using survival rates ranging from .3 to .72. There is evidence that these rates can be

achieved in certain cases. It is not known, however, what the appropriate rate will be for Lake Sammamish kokanee captive brood. There is no certainty that the actual rate achieved will fall within this range.

Fish health – Disease can be a limiting factor for fish culture operations. There are well established practices for addressing common fish health issues. The diseases of most concern for this option are IHN and Bacterial Kidney Disease (BKD). The extended time of rearing may be especially problematic for BKD which can be catastrophic. Routine fish health inspections and aggressive disease prevention practices will be incorporated to lessen potential for major negative impacts of disease.

Genetic

Extinction – This option offers the potential for the most rapid relaxation of extinction risk among the options evaluated due to the potential for rapidly increasing numbers of progeny generated within few generations. Catastrophic loss within the hatchery or extremely low survival rates at various life stages could reduce effectiveness of this option, resulting in risks approaching or exceeding the no-action alternative.

Within-population variation – This option prevents further deterioration of within-population variation if prescribed spawning protocols are followed and survival rates at various life stages are achieved for each mating.

Among-population variation – This option is expected to maintain population structure and will be managed to avoid introgression with other genetic populations.

Domestication selection – The risk of domestication selection is at its maximum level among the fish culture-based options presented because this option proposes the longest period of time during which kokanee are exposed to culture conditions.

Ecological

Predation – As described above, there is ample evidence to suggest that predation may be among the most significant risks for kokanee in Lake Sammamish. The captive brood option will provide total protection from predation at all life history stages.

Competition – There are a number of potential forms of competition that could come into play for this and other options including competition for prey and space. This option will negate the effects of competition during the fish culture phase and initial generations of the program. A successful captive brood program has the potential to quickly produce large numbers of juveniles for release to the natural environment. However, too little is known about early-run kokanee life history in Lake Sammamish and its relationship to lake productivity, habitat, and limnology to support conclusions about the potential for competition after release. The release levels suggested at an equilibrium program level

would produce a number of natural spawning adults at the low end of the historical ranges.

OPTION 5 - No Action

General Description

For this option, no early-run Issaquah Creek Kokanee would be raised for hatchery supplementation purposes. This option might be attractive if continued perpetuation of early-run kokanee without intervention via a hatchery-based program is expected. A presumed reversal of the recent stock decline or an expectation that limiting factors will be identified and relaxed, resulting in improved productivity, might also favor the no-action alternative. This option might also be acceptable if extinction of this population is an acceptable outcome. The no-action option might be considered despite the potential for extinction if spawning escapement is so low that a hatchery based program would be impractical or prohibitively costly. The early-run Issaquah Creek kokanee have been petitioned for listing under the Endangered Species Act. The no-action option might be acceptable if listing under the Endangered Species Act is either acceptable to managers, or is believed unlikely to occur.

Outcomes

No production outcomes were calculated. Under current conditions, the projected outcome for the no-action option is continued decline of Issaquah Creek early run kokanee at the rate of 6% per year (Connor, 2000), resulting in (functional) extinction presumably in the immediate future if in fact the population is not extinct at this time.

Risk Elements

Genetic

Extinction – This option presents the maximum risk of extinction among all options evaluated if the rate of decline is as reported in the literature and if a successful fish culture operation is assumed and survival rates at various life stages under artificial culture are achieved.

Within-population variation – There is potential for further loss of within-population variation if no action is taken if in fact there are adult kokanee remaining in this population.

Among-population variation – A loss of among-population variation will occur if this population becomes extinct.

Domestication selection – This form of genetic risk is not an issue with this option.

Ecological

Predation – As described above, there is ample evidence to suggest that predation may be among the most significant risks for kokanee in Lake Sammamish. The no-action option will provide no change in the current exposure to predation. However, there is little empirical information available to quantify the existing impacts of predation on early-run Lake Sammamish kokanee.

Competition – There are a number of potential forms of competition that could be affecting the current status of early-run kokanee. Too little is known about early-run kokanee life history in Lake Sammamish and its relationship to lake productivity, habitat, and limnology to support conclusions about the level of competition ongoing in the lake at this time. The literature suggests that other factors such as predation are sometimes a greater risk factor than competition. At current low kokanee population levels in Lake Sammamish, it is reasonable to suggest that competition is not limiting. The no-action alternative would not have an effect on competition.

IV. IMPLEMENTATION

This section first presents a discussion of general fish culture activities necessary to support the hatchery-based supplementation program for Lake Sammamish kokanee. A discussion of specific biological criteria including temperature requirements, loading rates, density rates, etc. follows. Biological criteria combined with projected production outcomes from tables 5 through 8 are used to derive detailed facility requirements for each supplementation option. Facility calculations are, in essence, projections of the rearing capacity (ft^3) and water flow (gpm) that should be incorporated into facility design. It is expected that information about biological criteria and facility requirements will provide the basis for project siting and procurement of necessary infrastructure.

GENERAL FISH CULTURE

Brood Collection

Issaquah Creek early-run kokanee enter Issaquah Creek between mid-July and early September (Connor 2000; Ostergaard 1998; Pfeifer 1995). A rack will be placed across the creek by July 15 to intercept adults as they enter Issaquah Creek. The rack will operate until approximately the first week of September, depending on presence of kokanee adults and within ESA permit parameters to protect fall chinook. The rack will be monitored 24 hrs per day to assure effective operation and to preclude harm to kokanee or chinook entering the facility.

Spawning

Kokanee are expected to enter the trap ripe and in spawning condition (Pfeifer 1995). A number of activities must be coordinated each day before spawning begins. Fish health staff must be available to collect and process viral and pathogen samples and samplers must be prepared to collect DNA and biological samples. Fish culture staff must confer with geneticists and confirm the mating schemes to be used given the number of spawners available for that day. All spawning apparatus including buckets, colanders, scales weigh-boats, vials etc must be available and laid out in preparation for spawning. A detailed operations document describing spawning and incubation protocols has been helpful in similar cases. The spawning operation will include the following elements:

- Length and weight data should be collected from each female before spawning. Individual females will be stripped of eggs using the excision method. Eggs from a single female will be placed in a numbered bucket and held in a cooler for fertilization. Viral samples will be collected by a fish health expert as eggs are removed from the female. DNA and appropriate biological data such as scale samples will be collected from each female after eggs are removed. If spawning is to occur off-site, unfertilized eggs from individual females will be placed in plastic bags or containers and transferred to the spawning site in a container with ice.
- Length and weight data should be collected from each male before spawning. Milt will be stripped from a like number of males and placed individually in numbered plastic beakers and placed in a cooler with ice until fertilization. DNA and appropriate biological data such as scale samples will be collected from each male after milt is removed. If spawning is to occur off-site, milt will be placed in individual numbered bags or plastic containers and transported to the spawning site in a container with ice.
- At the spawning site, biological data will be collected including egg number and egg weight. Eggs from individual females may be divided into two (or more) equal portions prior to fertilization to support factorial mating .
- Milt from each male will be divided into the appropriate number of portions to perform factorial matings. In some cases such as a limited availability of females, individual matings will be necessary. Consult with project geneticist prior to each spawning.
- Milt will be combined with green eggs to achieve fertilization. Fertilized eggs from individual females will be recombined, placed in iso-buckets, and water hardened in iodophore following protocols to be provided by fish health experts.
- Following the water-hardening procedure, iso-buckets containing the eggs from a single female will be situated for incubation.

Incubation

The egg incubation typically includes two stages. Green eggs are incubated to the "eyed" stage (eyes of the embryo are clearly visible). At this point eggs are "shocked" and non-viable eggs are removed. Survival data are collected and the remaining eggs are situated for the second stage, incubation to hatching.

- When water-hardening is complete, numbered iso-buckets containing the eggs from a single female will be situated for incubation to the eyed stage.
- If necessary, chilled water will be introduced to manage incubation rates and subsequent emergence of fry. This element will be developed following identification of the preferred option.
- Concurrently, fish health experts will be processing samples collected during spawning to determine the status of each individual. Disposition of egg lots with positive viral or bacterial kidney disease status will be determined by fish health experts.
- At the eyed stage, eggs will be shocked following established fish culture practices. Mortality data will be recorded for each female. Live eggs should be enumerated.
- After shocking, eyed eggs are placed into incubators for hatching. Eggs from each individual female will be placed in a single tray of a vertical incubator fitted with heavy plastic netting for substrate (Fuss and Seidel 1987).

Rearing

Four fish rearing options have been presented to support supplementation of Issaquah Creek early-run kokanee. The options differ primarily in the duration of the rearing period and the increasing size of juveniles as the rearing period is extended. The following general elements are common to the fish rearing phase of all options.

- Fry will be distributed from incubators to rearing vessels as they approach button-up indicated by visual observation, condition factor, or ventral slit measurement.
- During the first supplementation cycle, kokanee from individual matings will be reared separately until release (fingerling release options) or until juvenile fish are large enough to accept family-unique marks (approximately 30 fish per pound in October). As production levels increase, it will be necessary to determine the point at which individual families or individual matings are no longer tracked, suggesting that progeny of several matings can be combined for the rearing period.
- Biological rearing criteria will be followed throughout the rearing cycle.
- Feeding procedures will follow established practices. Various commercial diets are available and have proven to be successful for rearing both sockeye and kokanee . Fish culture experts will be expected to exercise feeding regimes that provide target sizes at the appropriate check points.
- Fish health preventative management practices are well established (WDFW/Co-Managers Statewide Disease Policy). Proper hygiene must be followed including routine disinfection of tools, pond cleaning and maintenance, prophylactic treatments, and therapeutic treatments as necessary.
- A significant amount of data collection will be necessary to support a robust monitoring effort. Data needs and formats should be provided in a detailed monitoring plan.

FACILITY DESIGN CRITERIA

Several biologically-based criteria are incorporated in the design and operation of a

hatchery-based project. These criteria are used to determine the fish rearing capacity of an existing facility or, in this case, to describe fish rearing capacity requirements for a proposed facility.

The most important input for hatchery design is to determine required carrying capacity. Carrying capacity is a product of water flow, rearing container volume, exchange rate, water temperature, dissolved oxygen, elevation, fish size, and fish species (WDFW 1996). Carrying capacity is expressed as the load or pounds of fish per gallon per minute inflow (lbs/gpm) and the density or pounds of fish per cubic foot of water volume (lbs/ft^3).

To calculate appropriate loading or density values, we incorporate accepted flow and density indices that correlate dissolved oxygen, elevation, and water temperature with fish size (Piper, 1982; WDFW 1996).

Facility design also incorporates water quality parameters, rearing vessel design, and the number of fish to be reared. All of these factors are combined to calculate the number of rearing vessels and the amount of water flow necessary to achieve the proposed production levels. The criteria used to calculate facility design capacity for the proposed kokanee rearing options are:

Volume

Incubation	
Iso-buckets	One mating per bucket
Vertical Incubators	*One mating per tray (initial stages of program)*
Rearing	
Density index	
Release Options	.3 lbs/ft^3/inch of length
Captive brood	.15 lbs/ft^3/inch of length but not to exceed .5 fish/lb @ 45 fish/lb and 1.0 lbs/gpm thereafter

Flow

Incubation	
Iso-buckets	.3 gpm per bucket
Vertical incubators	5 gpm per stack
Rearing	
Loading index	
All Options	1.8 lbs/gpm/inch of length
Water turnover rate	1.5 interchanges/hour per vessel
Design flow/circular pond	
3 ft diameter	1.88 gpm
4 ft diameter	4.5 gpm
10 ft diameter	40 gpm
15 ft diameter	130 gmp

20 ft diameter	234 gpm

Water Quality

Incubation	
Temperature	Not to exceed 50° F Chill to 35° F as necessary to control emergence timing
Source	Ground water – Pathogen free
Rearing	
Temperature	Not to exceed 50° F
Source	Ground water – Pathogen free Surface water for imprinting if indicated

Vessels

Incubators	
Green-to-eyed eggs	Iso-Buckets
Eyed egg-to-hatching	Vertical stack incubators
Rearing vessels	
Circular Ponds	
Approximate volumes	3 ft diameter – 10 ft^3 4 ft diameter – 24 ft^3 10 ft diameter – 235 ft^3 15 ft diameter – 700 ft^3 20 ft diameter – 1,256 ft^3

CAPACITY REQUIREMENTS

Calculations using the biological criteria presented above when applied to numerical predictions from Tables 1 – 4 lead to quantified capacity requirements for any program permutation of interest. From among the numerous permutations that could be calculated, four sets of results were developed: 1) instantaneous final capacities for each release-based option at initial program level, 2) instantaneous final capacities for each release-based option at equilibrium program level (see objectives), 3) instantaneous final capacities for the captive brood option at initial program level and, 4) instantaneous capacities for the captive brood option at equilibrium program level (Tables 5 - 8). Instantaneous final capacity is used because it represents the capacity necessary to accommodate the production at the point of ultimate size and weight.

Because density (volume) is invariably more constraining than loading (flow) for every permutation, all capacities are based on volume requirements. Flow requirements are derived secondarily based the single criteria of 1.5 exchanges per hour in each vessel. Each table is prefaced by a short explanation of considerations unique to that set of results.

Note that for each permutation, only a single brood is represented. Identification of the

total instantaneous rearing capacity may require the addition of two or more permutations depending on the preferred option. For example, if a yearling release program is the preferred option, then capacity for two successive brood years at different life stages must be available. For captive brood, four generations of brood stock could conceivably be on hand concurrently.

Release-based Options at Initial Program Levels (Table 5)

Each fish rearing option assumes, for the initial cycle, that all available brood stock will be retained for the project and the number of matings or families will range from five to 25. It is further assumed that each family will be kept separate until release or, in the case of the yearling release option, families will not be combined until fish can be marked at about 30 fish per pound in the fall after several months of rearing. Typically, capacity calculations are driven by total pounds of fish to be held for rearing. In this particular case, because we require families to be raised separately, the number of rearing vessels is dictated first by the number of families and then by the number of pounds (volume) required for each family. The result is apparent in Table 5 in which the number of ponds required (and, therefore, flow required) for Option 1 or 2 exceeds the absolute volume that would be suggested by the total weight of the fish on hand. In addition, the number of vessels required is always rounded up to whole numbers which will suggest excess capacity compared to a precise calculated volume. In all other respects the table is based on the outcomes and biological criteria described above. Annual costs to initiate Option 1 for the first cycle are shown in **Attachment 1.**

Table 5. Instantaneous final capacities for each release-based option at initial program level

	5 Families					25 Families				
Option	Release Number	Total Weight (lbs)	Volume (ft^3)	Vessels	Flow (gpm)	Release Number	Total Weight (lbs)	Volume (ft^3)	Vessels	Flow (gpm)
Fingerling	1,479	30	37			7,395	150	135		
Vessels										
3 ft diam				5	10				25	47
Fingerling-Extended	1,392	47	36			6,960	232	176		
Vessels										
3 ft diam				5	10				25	47
Yearling	1,305	87	53			6,525	435	264		
Vessels										
4 ft diam or;				2	9				11	50
10 ft diam				1	40				2	80

Release-based Options at Equilibrium Program Level (Table 6)

Table 6 presents an array of capacity requirements for fish release options that have achieved equilibrium as described in the objectives. At equilibrium, the number of fish needed for release is constant, for any post-release survival rated experienced. For this table, capacities are

presented for the same range of survival rates used to project the outcomes (see Tables 1 – 3). In this case, individual families would not be reared in separate vessels so capacity calculations are driven by weight of fish on hand. As in the previous table, the number of vessels required is always rounded up to whole numbers which will suggest excess capacity compared to a precise calculated volume. In all other respects the table is based on the outcomes and biological criteria described above.

Table 6. Instantaneous final capacities for each release-based option at equilibrium program level (1,000 adults)				
	Post-Release Survival Ranges			
	.01	.015	.02	.025
Release number	100,000	66,666	50,000	40,000
Option #1				
Weight (lbs)	2,000	1,333	1,000	800
Volume (ft^3)	1,802	1,200	900	720
Vessels/flow(gpm)				
3 ft diam or;	180/338	120/226	90/170	72/135
4 ft diam or;	75/338	50/225	38/171	30/135
10 ft diam or;	8/320	5/200	4/160	3/120
15 ft diam	3/390	2/260	2/260	2/260
Option #2				
Weight (lbs)	3,333	2,222	1,667	1,333
Volume (ft^3)	2,525	1,684	1,263	1,010
Vessels/flow(gpm)				
3 ft diam or;	253/476	168/316	126/237	101/190
4 ft diam or;	105/473	70/315	53/239	42/189
10 ft diam or;	11/440	8/320	6/240	5/200
15 ft diam	4/520	3/390	2/260	2/260
Option #3				
Weight (lbs)	6,667	4,444	3,333	2,667
Volume (ft^3)	4,040	2,693	2,020	1,616
Vessels/flow(gpm)				
4 ft diam or;	168/756	112/504	84/378	67/302
10 ft diam or;	18/720	12/480	9/360	7/280
15 ft diam or;	6/780	4/520	3/390	3/390
20 ft diam	4/936	3/702	2/468	2/468

Captive Brood Option at Initial Program Levels (Table 7)

Each fish rearing option assumes, for the initial cycle, that all available brood stock will be retained for the project and the number of matings or families will range from five to 25. For captive brood it is further assumed that each family will be kept separate until individuals are large enough to accept a mark that can identify each individual to its family of origin. Because we require families to be raised separately until marking, the number of rearing vessels is dictated first by the number of families and then by the number of pounds (volume) required for each family. After marking juvenile fish can be combined and calculations for later life stages are driven by total weight of fish on hand. In Table 7 the results are presented for the most optimistic survival

rates to adult maturation (.72). In addition, capacity requirements are presented for several alternative vessel sizes.

As in the previous tables, the number of vessels required is always rounded up to whole numbers which will suggest excess capacity compared to a precise calculated volume. In all other respects the table is based on the outcomes and biological criteria described above.

Table 7. Instantaneous final capacities for captive brood option at initial program level (.72 survival rate)

	5 Families					25 Families				
Life Stage	Fish Number	Total Weight (lbs)	Volume (ft^3)	Vessels	Flow (gpm)	Fish Number	Total Weight (lbs)	Volume (ft^3)	Vessels	Flow (gpm)
Fingerling-Extended	1,392	47	71			6,960	232	352		
Vessels										
4 ft diam				5	10				25	113
Adult	1,253	1,253	1,253			6,264	6,264	6,264		
Vessels										
10 ft diam				6	240				27	1,080
15 ft diam				2	260				9	1,170
20 ft diam				1	234				5	1,170

Captive Brood Option at Equilibrium Program Level (Table 8)

Table 8 presents an array of capacity requirements for a captive brood program that has achieved equilibrium as described in the objectives. At equilibrium, the number of captive brood adults expected for spawning is fixed (650). However, the number of juveniles needed at the beginning of each generation depends on the expected survival rate from eyed egg to adult spawner. For this table, capacities are presented at interim and final life stages for the range of survival rates shown in Table 4 (.3 - .72). In this case, individual families would not be reared in separate vessels so capacity calculations are driven by weight of fish on hand. As in the previous table, the number of vessels required is always rounded up to whole numbers which will suggest excess capacity compared to a precise calculated volume. In all other respects the table is based on the outcomes and biological criteria described above.

Table 8. Instantaneous final capacities for the captive brood option at equilibrium program level (650 adults)			
	Survival Rate to Adult		
	.30	.50	.72
Initial fry number	2,167	1,300	902
Fingerling-extended			
Weight (lbs)	72	43	30
Volume (ft^3)	109	65	45
Vessels/flow(gpm)			
4 ft diam	5/23	3/14	2/19
Adult			
Weight (lbs)	650	650	650
Volume (ft^3)	650	650	650
Vessels/flow(gpm)			
10 ft diam or;	3/120	3/120	3/120
15 ft diam	2/260	2,260	2/260

V. MONITORING AND EVALUATION

"Monitoring the effects of artificial propagation on the restoration of a threatened or endangered species should be a hallmark of a well-designed recovery plan. Supplementation is an experimental technique with a largely unproven record" (Hard et al. 1992). Initiation of a supplementation project for early run Issaquah Creek kokanee must be complemented with an extensive monitoring and evaluation effort. A two-tiered approach is proposed with the first tier designed to directly measure the response of the kokanee resource to the supplementation effort, if implemented. The second tier will provide necessary information on resource status, limiting factors and limnological conditions in Lake Sammamish. Pfeifer (1995; 1999) and Connor (2000) provided detailed discussions of monitoring and evaluation information needs as they relate to recovery of early run Issaquah Creek kokanee. The following discussion will focus on first tier monitoring and evaluation.

The first tier supplementation monitoring and evaluation program should validate and refine the initial assumptions used to design the supplementation strategy. This will include, for example, validation of performance assumptions such as survival rates projected for various life stages. The M&E plan must also evaluate the efficacy of risk containment measures and must monitor demographic and phenotypic traits to determine if the supplementation strategy is resulting in undesirable or unanticipated changes to the population. The following items should be included in the monitoring and evaluation package:

Adult capture date – baseline characterization of the population and subsequent detection of shifts in return timing.

Adult sex – Initial sex ratios and subsequent tracking of changes in sex ratio.

Adult length/weight – baseline characterization of the population and subsequent detection of shifts in size-at-age.

Adult scales – baseline characterization, age class analysis and potential to determine life history strategies.

Adult otoliths – baseline characterization, parental sources (resident or anadromous) and potential to separate juveniles and adults originating from the supplementation program from non-supplemented groups.

DNA – baseline characterization of the population, detection of straying, and subsequent monitoring of efficacy of genetic risk containment approaches.

Pathogen sampling – establish fish health status and screen for viral pathogens affecting management decisions.

Egg weight and size and number – baseline characterization and subsequent detection of changes in demographics in response to changes in adult age structure and size-at-age.

Green egg to eyed egg viability – validate initial performance assumptions and refine production outcomes; track performance changes or response to refined fish culture techniques.

Eyed egg to fry survival – validate initial performance assumptions and refine production outcomes; track performance changes or response to refined fish culture techniques.

Periodic length/weight – Validate initial performance assumptions and refine production outcomes; refine growth and feeding rates; track performance changes and response to refined fish culture techniques.

Feed conversions – refine size and growth projections; program growth to achieve desired target sizes.

Size at release – Validate initial performance assumptions and refine production outcomes; relate size at release to post-release survival and subsequent adult production.

Environmental conditions including temperature, flow, densities – monitor rearing conditions to remain within criteria; correlate environmental conditions with performance and fish health.

Fish health monitoring – routine inspections and response to fish health status as

necessary.

Adult survival to return – Validate initial performance assumptions and refine production outcomes.

Second tier information is also critical to the success of the supplementation effort and to the ultimate recovery of early run Issaquah Creek kokanee. Second tier monitoring and evaluation needs should be developed in detail in the kokanee recovery plan. However Pfeifer (1995) presented an excellent prototypical list including:

Limiting factors –
- spawning and passage conditions (adult and fry) below R.M. 3.8
- sediment and flooding concurrent with emergence time
- redd superimposition
- water quality including lake temperature and oxygen level
- predation/poaching
- compensatory mortality
- competition/displacement by sockeye
- competition with chinook for space and forage

Enhanced escapement surveys
Baseline information on life history and abundance
Survival rates at various life history stages
Lake limnology

VI. REFERENCES

Beauchamp, D.A., M.G. LaRiviere, and G.L. Thomas. 1995. Evaluation of competition and predation as limits to juvenile kokanee and sockeye salmon production in Lake Ozette, Washington. N. Am. J. Fish. Manage, 15:193-207.

Busack, C. A. and K. P. Currens. 1995. Genetic risks and hazards in hatchery operations: Fundamental concepts and issues. IN: Uses and Effects of Cultured Fishes in Aquatic Ecosystems, H.L. Schramm, Jr. and R. G. Piper *eds*, American Fisheries Society Symposium 15: 71-80.

Connor, E., B. Kvam and L. Mighetto. 2000. Historic and current status of kokanee in the Lake Washington basin. Discussion draft, March 13, 2000. Prepared for King County, WA by R2 Research Consultants, Inc., Redmond, WA. With historical research by Historical Research Associates, Inc., Seattle, WA., 44 pp.

Flagg, T.A. and C.V.W. Mahnken. 1995. An assessment of the status of captive broodstock technology for pacific salmon. Final Report to the Bonneville Power Administration, Contract DE-AI79-93BP55064, 299 pp.

Flagg, T. A., and C.E. Nash (editors). 1999. A conceptual frame work for conservation hatchery strategies for Pacific salmonids. U.S. Department of Commerce, NOAA Tech. Memo. NMFS-NWFSC-38, 38 pp.

Flagg, T.A., W. C. McAuley, D.A. Frost, M.R. Wastek, W.T. Fairgrieve, C.V.W. Mahnken. 2001. National Marine Fisheries Service, Redfish Lake sockeye salmon captive broodstock rearing and research, 1995-2000. Annual Report to Bonneville Power Administration, Contract 1992BP41841, 71 electronic pp.

Fuss, H.J. and C. Ashbrook. 1995. Hatchery operations plans and performance summaries, Vol. 1, No. 2, Puget Sound. Annual Report #95-10. Wa. Dept. Fish and Wildlife, Olympia, WA.

Fuss, H. and P. Seidel. 1987. Hatchery incubation techniques at WDFW hatcheries. Technical Report No. 100. Wa. Dept. of Fish and Wildlife, Olympia, WA., 86 pp.

Hard, J. J., R. P. Jones Jr., M. R. Delarm, and R. S. Waples. 1992. Pacific salmon and artificial propagation under the endangered species act. U.S. Department of Commerce, NOAA Tech. Memo. NMFS-NWFSC-2, 56 pp.

The Independent Science Group (ISG). 1996. Return to the river; restoration of salmonid fishes in the Columbia River system. Northwest Power Planning Council, Portland, OR., 584 pp. (Available from Northwest Power Planning Council, 851 Sixth Avenue, Portland, OR, 97204-1348).

Marlowe, C., B. Freymond, R.W. Rogers, and G. Volkhardt. 2001. Dungeness River chinook salmon rebuilding project, Progress Report 1993-1998. Report #FPA 00-24, Wa. Dept. Fish and Wildlife, Olympia, WA., 96 pp.

Miller, W.H., T.C. Coley, H.L. Burge, and T.T. Kisanuki. 1990. Analysis of salmon and steelhead supplementation: emphasis on unpublished reports and present programs. IN: W.H. Miller (ed), Analysis of salmon and steelhead supplementation. Report to the Bonneville Power Administration, Contract DE-A179-88BP92663, 202 pp. (Available from Bonneville Power Administration, P.O. Box 3621, Portland, OR)

Murdoch, A., and K. Petersen. 2000. Survey of sockeye, spring chinook and summer chinook salmon released fro Rock Island Fish Hatchery Complex facilities (1989 – 1995 broods). Annual report #FPA00-06, Wa. Dept. Fish and Wildlife. Prepared for Chelan Public Utilities District #1, Chelaon Co., WA.

National Marine Fisheries Service (NMFS) 2000. Supplemental Biological Opinion –Operation of the federal Columbia River power system including the Smolt Monitoring Program and the Juvenile Fish Transportation Program: A supplemental to the Biological Opinions signed on March 2, 1995, May 14, 1998, December 9, 1999 and February 4, 2000.

National Research Council (NRC). 1995. Upstream: salmon and society in the Pacific Northwest, National Academy of Science, Washington D.C., 452 pp.

Northwest Power Planning Council (NWPPC). 1999. Artificial production review. Council document 99-15. Northwest Power Planning Council, Portland, OR., 238 pp.

Ostergaard, E. 1998. 1996 salmon spawning surveys in the Lake Washington watershed: Results of the 1996 Salmon Spawning Survey Program and Kokanee Spawner Survey Program. King County Department of Natural Resources, Seattle, WA. 41 pp plus appendices.

Pfeifer, Bob. 1995. Decision document for the management and restoration of indigenous kokanee of the Lake Sammamish/Sammamish river basins with special emphasis on the Issaquah Creek stock. Wa. Dept. Fish and Wildlife, unpublished manuscript. 44 pp.

Pfeifer, Bob. 1999. Recovery options and plan for early-entry Issaquah Creek kokanee in Lake Sammamish. Wa. Dept. Fish and Wildlife, unpublished manuscript. 31 pp.

Piper, G.R., I.B. McElwain, L.E. Orme, J.P. McCraren, L. G. Fowler, and J.R. Leonard. 1982. Fish Hatchery Management. U.S. Department of Interior, Fish and Wildlife Service, Washington, D.C. 517 pp.

Steward, C.R. and T.C. Bjornn. 1990. Supplementation of salmon and steelhead stocks with hatchery fish: a synthesis of published literature, Tech Report 90-1. IN: W.H Miller (ed),

analysis of salmon and steelhead supplementation. Report to the Bonneville Power Administration, Contract DE-AI79-88BP92663, 202 pp. (Available from Bonneville Power Administration, P.O. Box 3621, Portland, OR.)

Smith, E.M., B.A. Miller, J.D. Rodgers, and M.A. Buckman. 195. Outplanting anadromous salmon. Annual Report to the Bonneville Power Administration, Contract DE-A179-85BP23109, 68 pp. (Available from Bonneville Power Administration, P.O. Box 3621, Portland, OR.)

Washington Department of Fish and Wildlife (WDFW). 1996. Fish Health Manual. Wa. Dept. Fish and Wildlife, Olympia, WA.

ATTACHMENT 1

EARLY KOKANEE BROOD COLLECTION AND REARING BUDGET ESTIMATE

SCOPE:

The intent of this budget document is to provide an estimate of near-term operational and monitoring costs adequate to support initial brood stock collection and short term rearing of a limited number of early-run kokanee. The proposed annual budget would allow collection of about ten pairs of adults per year and provide adequate funding for incubation and rearing of the resultant fry until about June of the following year.

This approach provides the opportunity to launch a modest supplementation project by obligating to only that portion common to most of the available long-term supplementation options. That is, the fish culture activities proposed in this budget would be common to all options including fry releases, yearling releases, or captive brood.

The budget beyond the first cycle would be derived following selection of a specific long-term supplementation approach. In the event a no-action alternative was chosen, all fry on hand would be released and the project terminated. For all other alternatives, the budget amount would be determined according to the supplementation option selected and an assumed rate of increase in production capacity during rebuilding years.

ASSUMPTIONS:

Brood collection period
- 15 July through 2 September
- Security 24 hrs/day during brood collection
- Ten families spawned

Incubation
- isolation incubation required for disease assessment
- from spawning through 30 November
- families or individual matings maintained separately

Rearing
- families raised in individual containers
- fish raised to 50 fish per pound (9g)
- rearing period December through June

BUDGET:

Brood Collection

Permit costs		uncertain
Rack and trap design, materials, install and remove		$21,000
Staffing (4 staff; 24 hr coverage)		13,450
Virologist (2-3 days)		718
Supplies (nets, brooms, rain gear, life vests, etc)		600
Site security (cell phones, trailer, sewerage, power etc.)		1,500
Vehicle use for spawning and egg transport		85
Egg/milt collection and transport supplies (coolers, vials, ice, jars, etc.)		200
	SubTotal	$37,553

Incubation

Chiller to reduce incubation temperature to 35° F[1/]		$35,000
Iso-bucket incubators (10 @ $30 and plumbing)		500
Pumping costs ($4.50/mo/gpmx25gpm)		1,350
Staff (egg shocking, picking, record keeping, etc)		7,950
Verticle incubators (1/2 stack, 5 @ $800 plus plumbing)		5,000
Virology samples processed ($20/fish)		200
Sundries		200
	SubTotal	$50,200

Rearing

Rearing vessels (10 circulars, center drain, plumbing to source)		$20,000
Pumping costs ($4.50/mo/gpmx50gpm)		2,700
Staff		18,550
Pathologist services		2,685
Feed (approximately 60 lbs gain)		150
	SubTotal	$44,085

Monitoring

Baseline otolith and DNA		$11,000
Baseline stream surveys		20,000
Biosampling (response to supplementation)		10,000
Stomach analysis (predator impacts)		5,000
Marking (visible for segregation of families at spawning)		1,000
Hydroacoustics		10,000
Stream surveys		12,000
	SubTotal	$69,000
Project Management/Oversight		$40,000
[1/] one-time cost for Option 2, 3, 4	**TOTAL**	**$240,838**